



THERMAL ASPECTS OF LITHIUM ION CELLS

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OBJECTIVE

Develop thermal model of Li-Ion cells in terms of heat generation, thermal mass, and thermal resistance. Intended for incorporation into battery model.

APPROACH

Heat Generation:

- Estimate rates with semi-theoretical model
- Check accuracy with efficiency measurements

Thermal Mass:

- Compute from component weights and specific heats

Thermal Resistance:

- Compute from component dimensions & conductivities

METHOD FOR ESTIMATING HEAT GENERATION RATE

$$Q = I (V_{oc} - V)$$

where:

Q = instantaneous cell heat generation at given current (I), temperature (T), and state-of-charge (SOC)

I = Cell current , amps

V_{oc} = open circuit voltage (V) at given T, and SOC, volts

V = operating voltage at given I, T, and SOC, volts

INPUT DATA OBTAINED EXPERIMENTALLY

V_{oc} as a function of SOC and T

V as a function of SOC, I, and T

Component Properties

Prismatic lithium cell					
length, Lx	0.118	m			
width, Ly	0.091	m			
thickness,Lz	0.027	m			
area	0.010738	m ²			
Conductivities					
kpara along x or y	26.69	W/mK			
keff=kz in the normal direction	1.848	W/mK			
RESISTANCES					
Rperp_whole cell, Rz	1.379	K/W			
Rx, along length	1.778	K/W			
Ry, along width	1.049	K/W			
Ral_tab	21.14	K/W			
R_all_tabs	0.128	K/W			
mass and thermal properties					
	mass,kg	cp,J/kg K	density,kg/m ³	k, W/mK	mass*cp J/K
can stainless	0.169	502.8	7800	16.3	84.9732
A_coating	0.184	838	1800	5	154.192
C_coating	0.228	838	1800	5	191.064
Copper substrate	0.077	385.48	8900	381.29	29.68196
Al substrate	0.043	905.04	2700	201.12	38.91672
separator	0.02	1676	900	0.2	33.52
electrolyte	0.146	2514	1200	0.1676	367.044
TOTAL	0.867				899.39188 thermal mass



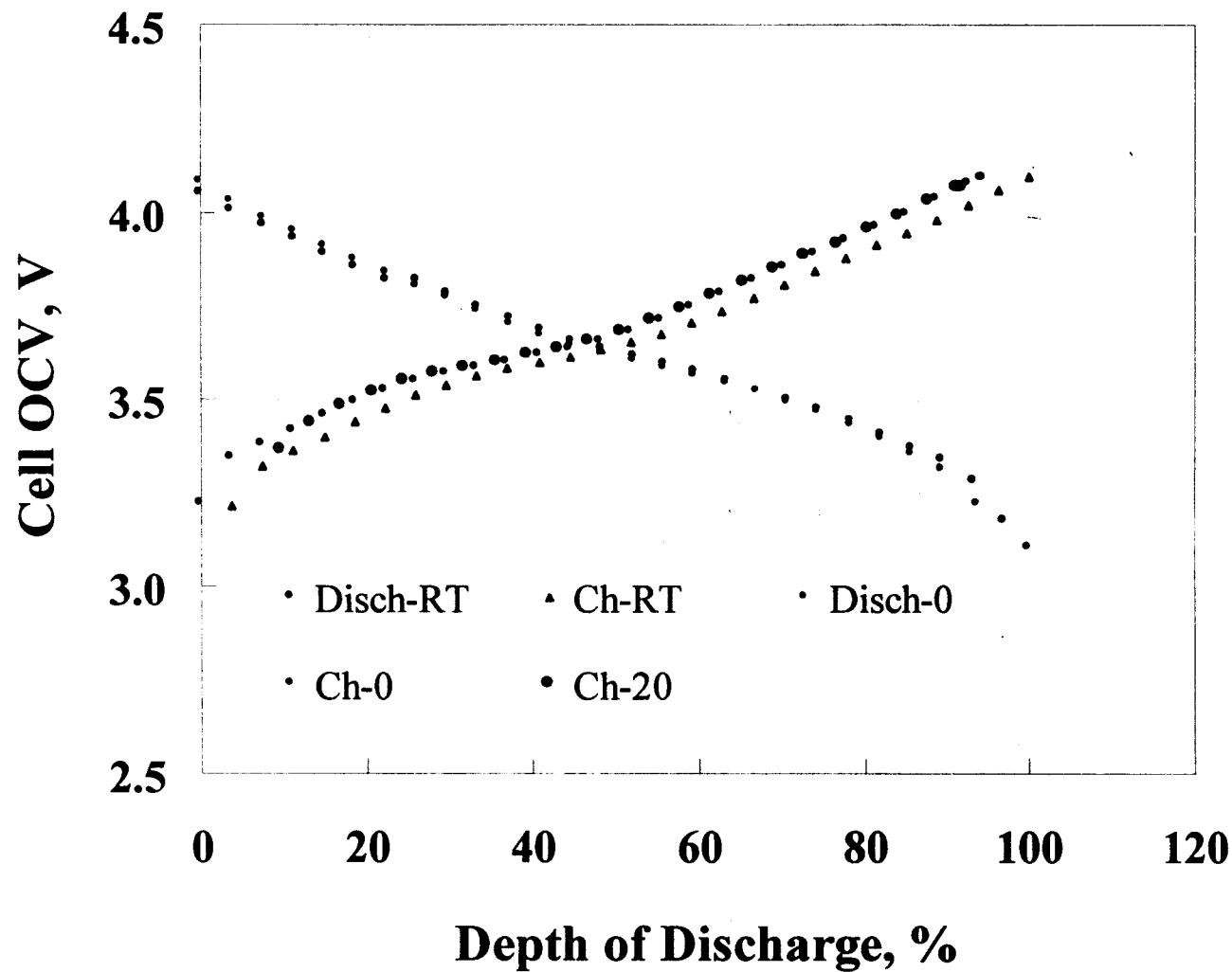
Properties of components

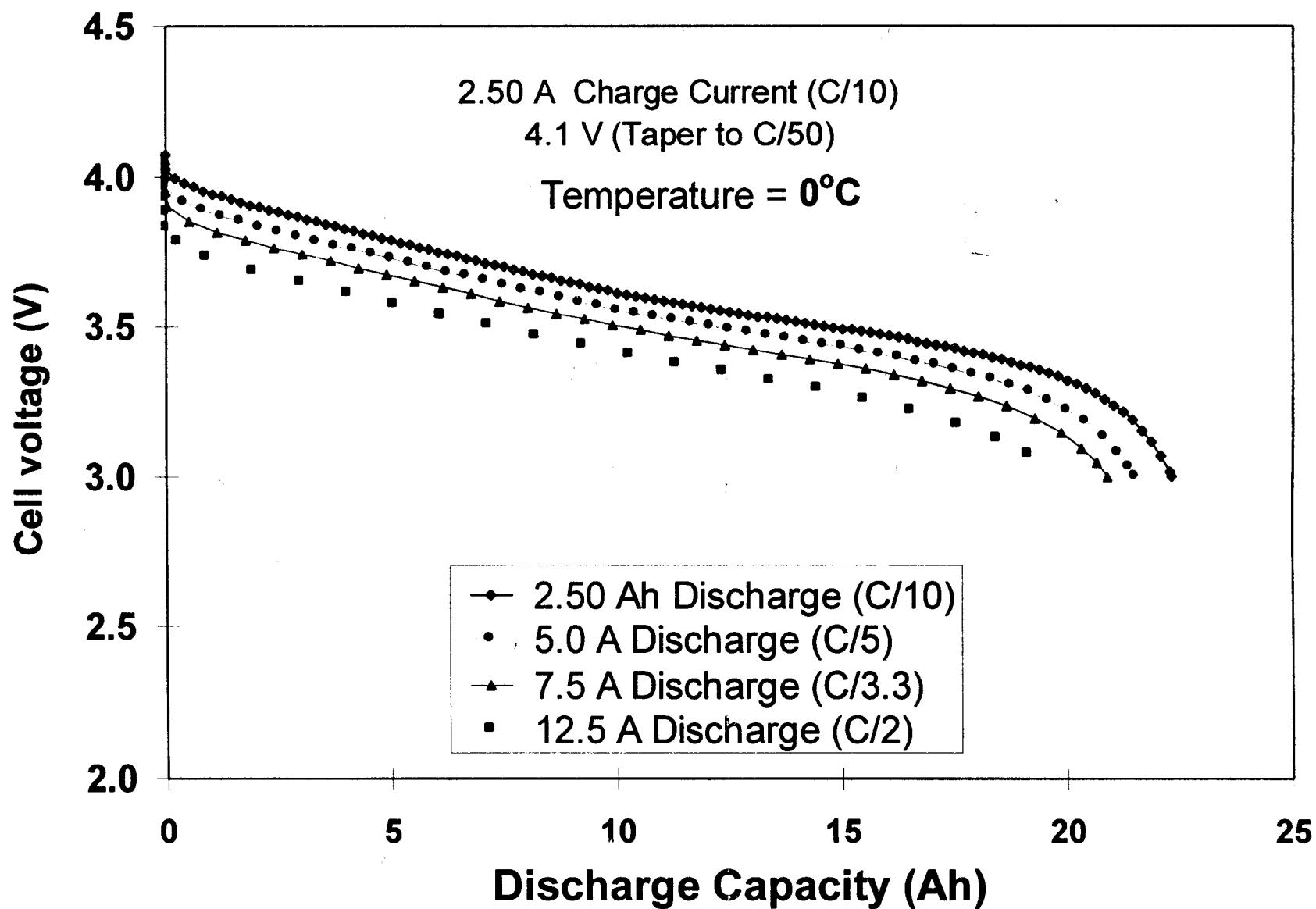
Cylindrical lithium battery					
length, Lx or height	0.192	m			
diameter	0.047	m			
Conductivities					
kpara along x	57	W/mK			
keff=kz in the normal direction	1.73	W/mK			
RESISTANCES					
Rperp_whole cell, Rz	1.82	K/W			
Rx, along length	1.9425	K/W			
Ral_tab	77.7	K/W			
mass and thermal properties					
	mass,kg	cp,J/kg K	density,kg/m3	k, W/mK	mass*cp, J/oK
can stainless	0.126	502.8	7800	16.3	63.3528
A_coating	0.112	838	1800	5	93.856
C_coating	0.318	838	1800	5	266.484
Copper substrate	0.064	385.48	8900	381.29	24.67072
Al substrate	0.043	905.04	2700	201.12	38.91672
separator	0.027	1676	900	0.2	45.252
electrolyte	0.227	2514	1200	0.1676	570.678
TOTAL	0.917				1103.2 thermal mass



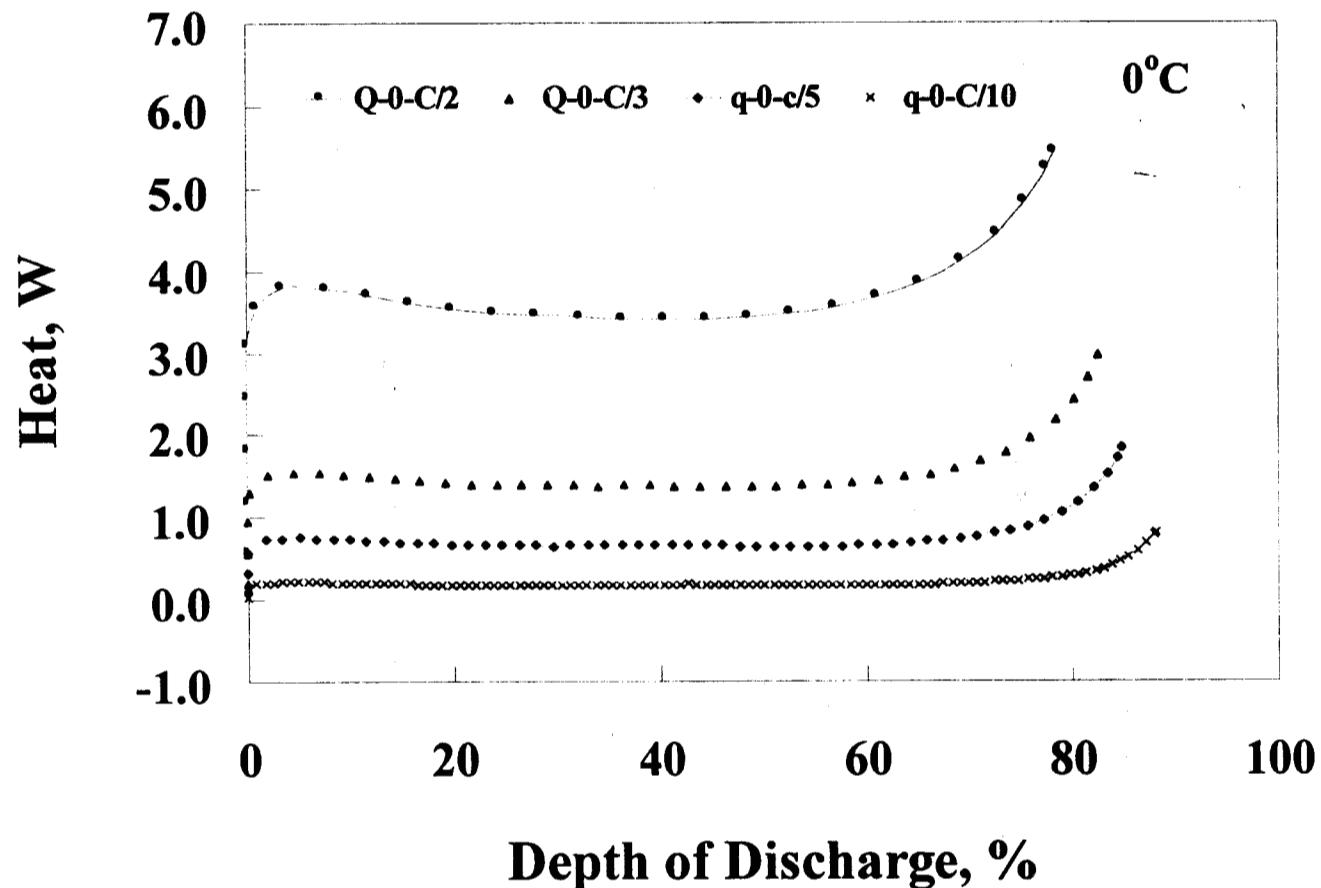
Radius r
0.0235m

Open-circuit Curves of Prismatic Li Ion cells

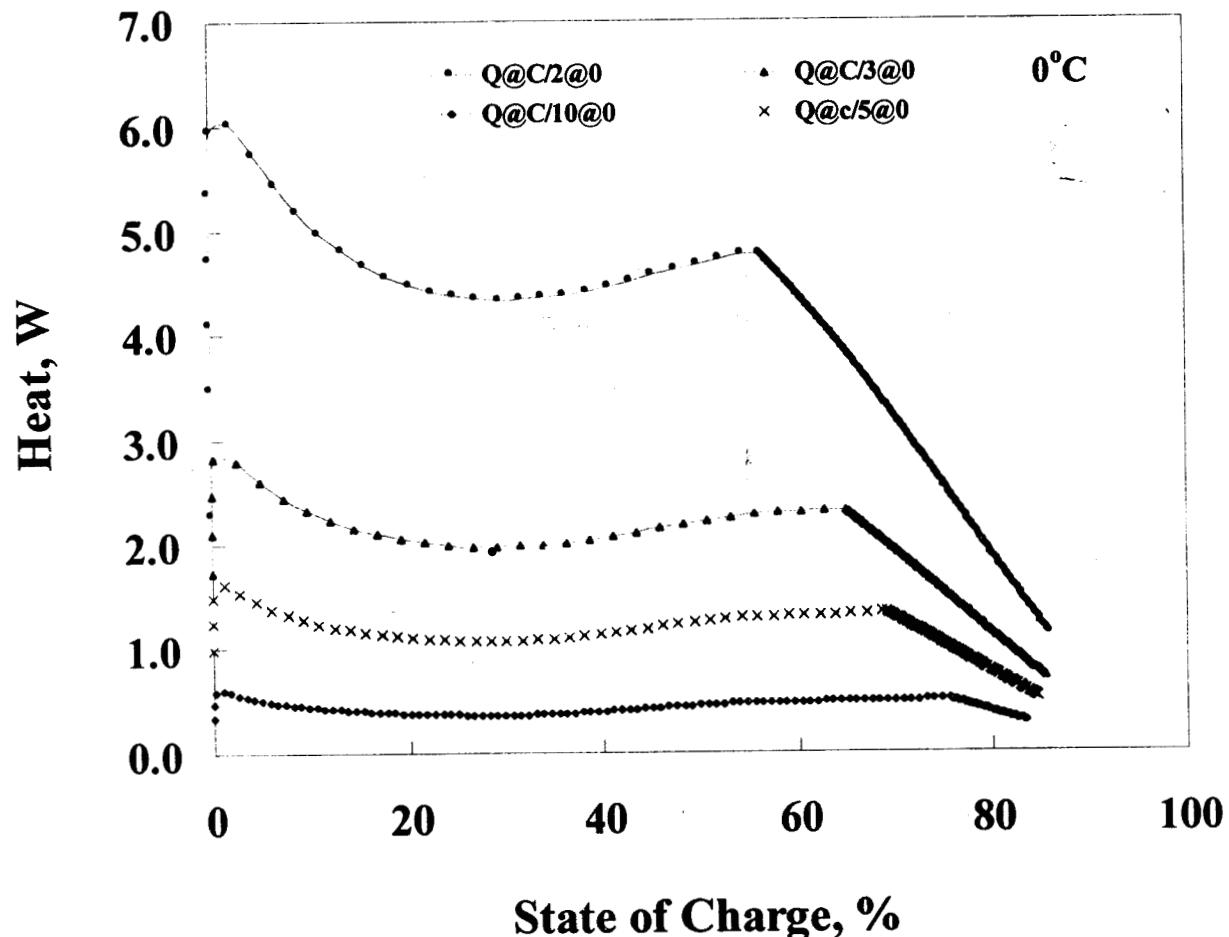




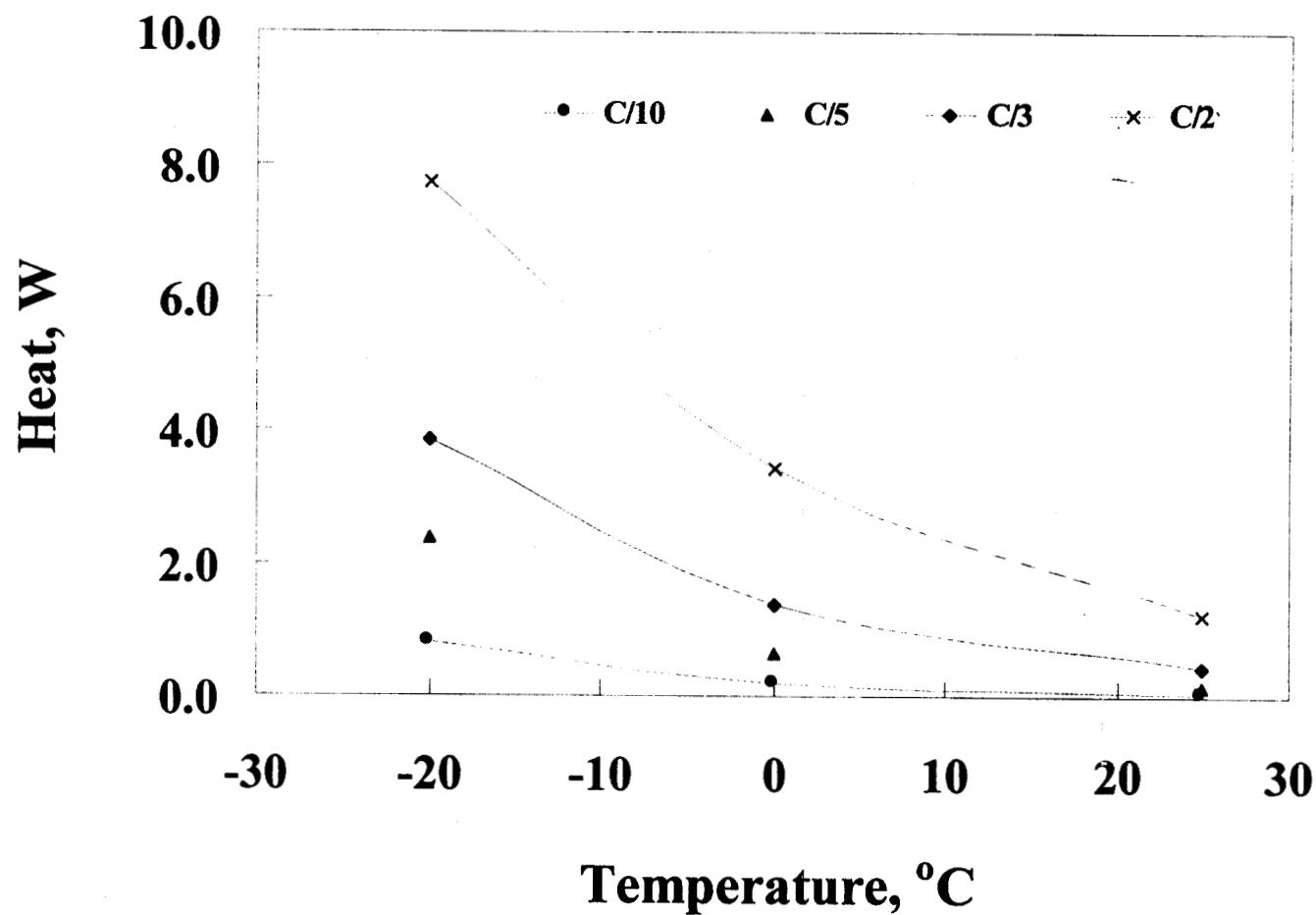
Heat Evolution During Discharge of Prismatic Cells



Heat Evolution During Charge of Prismatic Cells



Heat Evolution During Discharge of Prismatic Cells



VERIFICATION OF METHOD FOR ESTIMATING HEAT

**SHOW THAT TOTAL HEAT GENERATED FOR COMPLETE CYCLE CORRESPONDS TO DIFFERENCE BETWEEN
MEASURED ENERGY INPUT AND OUTPUT. EXAMPLE IS A CYCLE FOR THE PRISMAIC CELL:
C@2.5A and D@5 5.0A @25 oC**

Electrical Input for charge.....83.98 wh

Electrical Output for discharge.....76.24 wh

Difference (Input - Output)..... 7.74 wh

Integrated heat for charge..... 4.08 wh

Integrated heat for discharge.....3.31 wh

Total heat for cycle.....7.39 wh

Reasonably good correspondence of measured and predicted heat

CONCLUSIONS

25 AH Li-ION CELL

HEAT GENERATION

- Developed heat generation rate model as function of I, V, & SOC
- Heat proportional to I for C & D
- Heat increases with decrease in T
- Heat is relatively independent of SOC
- Typical Heat @ 5A, 0°C, & 50%DOD: 1.5W(D), 0.5W(C)
- Support for model shown by agreement of predicted heat (by integrating calculated values) and indirectly measured heat (from electrical efficiency data) for a complete cycle

CONCLUSIONS

(cont'd)

THERMAL MASS

Prismatic Cell.....900 J/ $^{\circ}$ K

Cylindrical Cell.....1103 J/ $^{\circ}$ K

THERMAL RESISTANCE

Prismatic (Perpendicular to plates).....1.4 $^{\circ}$ K/W

Prismatic (Parallel to plates,).....1.0-1.8 $^{\circ}$ K/W

Cylindrical (Perpendicular to plates, radial).....1.8 $^{\circ}$ K/W

Cylindrical (Parallel to plates, along height).....1.9 $^{\circ}$ K/W